Chapter 2

MAJOR PROCESSES SHAPING THE EVOLUTION OF AGRICULTURE, BIOTECHNOLOGY, AND BIODIVERSITY

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Abstract: The paper identifies five major global trends that are likely to impact agricultural biodiversity conservation and the adoption of agricultural biotechnologies. The trends covered include trade and capital market liberalization, the rise of the environmental movement, consumerism, privatization and devolution of government services, and the emergence of the information age. We find that trade liberalization is likely to lead to increased incentives and capacity for biotechnology adoption, with unclear but potentially negative impacts on agricultural biodiversity. Environmentalism has generated a system of environmental governance and regulation, which may come into conflict with those established under global trade agreements. However, the way in which these disputes will be resolved is still unclear, but it will likely have important implications for both agricultural biotechnology and biodiversity. The rise in consumer power associated with increased incomes and the expansion of markets will affect biotechnology adoption through two opposing effects: the expression of consumer concerns about environmental and food safety, balanced against the delivery of quality characteristics that biotechnology can deliver. Privatization in the agricultural research and development sector increases incentives for the development of agricultural biotechnologies, but may create barriers to their adoption in developing countries, while the privatization of environmental services generates increased incentives for biodiversity conservation. Rapid improvements in information technologies increase the capacity for effective biodiversity conservation and are fundamental components of the development of biotechnologies.

Key words: agricultural biodiversity; agricultural biotechnology; environmental treaties, globalization, information technologies; privatization.

Over the past 20 years, several global trends have been unfolding which have implications for the evolution of agricultural biotechnology and the conservation and sustainable use of agricultural biodiversity. These trends are interlinked and in some cases have opposing effects, and their final outcomes are yet to be determined. In this chapter we provide a short survey of these developments together with an analysis of their potential implications for the use of agricultural biotechnology and the management of agricultural biodiversity. The trends covered include trade and capital market liberalization, the rise of the environmental movement, consumerism, the privatization and devolution of government services, and the emergence of the information age.

Both biotechnology and the concept of biodiversity are fairly recent arrivals onto the human scene, and their management has raised several controversies. For example, biotechnology is a product that is comprised of a large intellectual component, e.g., it represents the culmination of a process of research. This research has mostly been carried out in the private sector, although it also often involves the use of genetic resources which originated in the public domain. There is considerable disagreement on the best means of protecting the property rights to the intellectual component embodied in biotechnology, while recognizing both the private and public contributions to the end product. In addition, agricultural biotechnology products are the result of a major scientific advance and have only very recently become available. Due to their novelty, there is only limited information on the long-run impacts they might have on environmental and food safety. A great deal of uncertainty exists on how much risk such products entail, as well as much controversy on how it should be measured and how much is socially acceptable.

Considerable uncertainty and conflict exist over the conservation of agricultural and wild biodiversity as well. Assigning values to biodiversity conservation is fraught with uncertainty. One of the most significant values associated with biodiversity is preserving potential future options for the use of the genetic resources maintained—and this is very difficult to assign value to. There is even considerable uncertainty with determining the use values of agricultural biodiversity, which ostensibly is easier to measure.

Uncertainty over values leads to controversy over conservation strategies: how much and what should be preserved. Controversy is particularly sharp when conservation conflicts with economic development (see Chapter 19).

These controversies are currently under discussion and negotiation in a variety of formal and informal forums, and they are being shaped by the global trends, which we identified in the first paragraph. In the discussion which follows below, we discuss how these global processes are shaping the ongoing debates in various contexts and draw conclusions as to their potential implications for the management and use of agricultural biotechnology and biodiversity in developing countries. Our discussion is kept to a fairly general level, which does not fully capture the tremendous variation that exists among developing countries in terms of their endowments and capacities. More specific analyses related to the management of biotechnology and agricultural biodiversity in the varied context of developing countries are given in later chapters of this book.

1. GLOBALIZATION OF TRADE AND CAPITAL MARKETS

Over the last 20 years, the volume of trade between countries has expanded remarkably as a result of the reduction of trade barriers, as well as decreasing costs in transport and communications and the increased mobility of capital across international boundaries. International and regional trade agreements have been the primary mechanism by which trade barriers have been lowered, such as the General Agreement on Trade and Tariffs (GATT), and subsequently the World Trade Organization (WTO) at the global level, and North American Free Trade Agreement (NAFTA), the European Community, and MERCOSUR[3] as examples of regional blocs.

Liberalization has also occurred in agricultural trade markets, although this is one of the most contentious areas of international trade policy and one where significant distortions still exist, particularly among developed countries. Indeed it was deadlock over agricultural trade which caused the breakdown of negotiations at the 2003 WTO meeting in Cancun. Nonetheless, there has been considerable movement towards the liberalization of agricultural trade markets, and more is expected in the future. In the United States, there is a move towards converting commodity support programs towards "green payments," e.g., paying for environmental services. In Europe, the expansion of the European Union is creating pressures to reform the Common Agricultural Policy (CAP) and reduce production supports. Farmers are increasingly expected to rely on insurance instruments provided by the private sector and sometimes subsidized by the government for the management of production and revenue risk. Future markets and forward contracts are also likely to play a major role in reducing risk in agriculture.

In basic grain markets, the impact has been a shift in production from high cost to a few lower cost producers such as the United States, Argentina, and Australia, as well as Thailand and Vietnam. At the same time many developing countries as well as the transition economies of Eastern Europe have become net importers of grain, and this trend is expected to continue with liberalization (Bruinsma, 2003).

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[3] El Mercado Común del Sur, includes Brazil, Argentina, Paraguay, and Uruguay.

If indeed agricultural support prices in developed countries are reduced, producer prices for some agricultural commodities are likely to increase in developing countries and new market opportunities created. One impact of these changes may be increased incentives for the adoption of new yield-increasing biotechnologies. Agricultural trade liberalization increases competitive pressures among producers and creates incentives for increasing yields and reducing costs in agriculture. It also exposes producers to the demand requirements of a larger group of consumers. This may expand the demand for both yield-increasing and pest-controlling biotechnology products. For example, the ability to export to markets in Japan, Canada, and other countries may be determined by the ability to control pest problems with minimal or no chemical residues. Concern about ozone depletion is leading to regulations banning the use of methyl bromide and other chemicals. These measures provide increased incentives for the adoption of pest-controlling biotechnology products.

By reducing investment barriers, trade liberalization creates the potential for investors such as multinational companies to invest in both production and marketing infrastructure in developing countries with promising commercial market potential, or which establish incentives to attract mobile capital. Profound changes are occurring in the organization of the food sector in developing countries due to globalization, as well as urbanization, increasing incomes, and the opportunity costs of food purchasing and preparation. The rise of multinational retail chains, supermarkets, fast food chains, and other forms of pre-prepared foods are manifestations of this change. The developments in the structure of food markets raise challenges and opportunities for local and global suppliers, and have implications for both agricultural biotechnology and biodiversity.

On the one hand, food producers can potentially take advantage of the income-earning opportunities created in a dynamic and rapidly expanding market. This could increase the demands for agricultural biotechnology and incentives to adopt among producers in order to remain competitive. On the other hand, small producers unable to adapt to the required institutional and organizational changes, and the technology and management requirements that they entail, risk marginalization in terms of market participation. Some evidence of this trend is available with concentration in the food supply chain linked to increased farm consolidation and reduced market participation among small producers (Reardon et al., 2003; Berdegué et al., 2003). It is not clear what impact this will have on either agricultural diversity or biotechnology, although it is likely to lead to a higher demand for biotechnology products from both the commercial farm sector and the food processing industries, but will reduce demand from small farmers

While agricultural trade liberalization may result in increased incentives for producers in developing countries to adopt agricultural biotechnology, the extent to which adoption actually will occur depends on the types of innovations biotechnology delivers, and the degree to which these substitute for scarce factors of production and address key production and consumption constraints (see Chapters 13 and 17). At present, agricultural biotechnology innovations are being developed primarily to reduce production costs or increase yields under conditions present in developed countries, which constitute the main market for these products. In many developing countries, production constraints are of a different nature than those in developed countries; barriers to productivity increases are often more related to controlling for the incidence of drought, poor soil quality, and high rates of pest and disease, whereas in developed countries reducing management costs and pesticide use are more important concerns. Trade liberalization may exert some positive influence on the commercial attractiveness of developing innovations to address these needs through its impact on the global demand for inputs; however, this will only apply to technologies that have the potential for a significant commercial market.

Even where technologies are suitable for the production conditions in developing countries, it will be necessary for countries to have in place an adequate level of research, extension, and regulation to achieve dissemination and adoption of such technologies (see Chapters 3, 14, 15, and 16) The institutional requirements are significantly higher and more sophisticated than has been the case in the past for the adoption of improved agricultural technologies. Issues such as biosafety regulation, the negotiation of intellectual property rights (IPRs), and the technological capacity to modify technologies to suit local conditions place fairly significant burdens on the research and development (R&D) infrastructure of developing countries, and the capacity to meet such demands varies widely among them.

An important effect which the liberalization of trade may have on both agricultural biotechnology adoption and the management of biodiversity is the degree to which consumer concerns for the environment and food safety are allowed to be manifested through trade regulations and labeling (Anderson and Nielsen, 2001). The key principle of the WTO is nondiscrimination among member states, e.g., a standardization of product definition and treatment. However, consumer preferences for the environmental and health attributes of agricultural products are heterogeneous across national boundaries and could potentially be manifested in trade regulations. The ability of countries to regulate trade based on environmental and food safety concerns and specifically the degree to which countries may apply their own standards to reflect such concerns are governed by two agreements made under the WTO: the Agreement on Sanitary and Phytosanitary Measures (SPS) and the Agreement on Technical Barriers to Trade (TBT) (Anderson and Nielsen, 2001; Josling, 1999). These agreements allow members to impose restrictions on trade based on environmental and food safety concerns, but they also seek to ensure that such regulations are no more trade restrictive than necessary by imposing restrictions on the use of such "nontariff barriers to trade." In addition, they do not apply to the processes by which agricultural and other goods are produced, but only to the products themselves, which limits the degree to which environmental and food safety concerns can be used to establish trade barriers (Anderson and Nielsen, 2001). Nonetheless, consumer concerns over the environment and food safety could potentially impact the production practices in exporting countries. Ultimately, this impact will depend on the type of specific attributes that are demanded, the willingness to pay among consumers for such attributes, the capacity to distinguish such characteristics in products (e.g., labeling), and the degree to which the expression of such preferences is allowed under the WTO regulations.

The WTO includes another important agreement that has major implications for the dissemination of biotechnology and the management of biodiversity: the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). The main thrust of this agreement is to facilitate trade in products that have a high intellectual property content. The agreement mandates a minimum standard for IPRs among member states, but leaves them free to determine the appropriate method of implementing them under their own legal system. Article (27.3(b)) of the agreement explicitly refers to the protection of plant varieties and stipulates that new varieties need to be protected either by patents or an "effective sui generis" system such as that of the International Union for the Protection of New Varieties of Plants (UPOV). Under the UPOV system of plant protection, plant breeders' and farmers' rights may be recognized; e.g., breeders have the right to use protected genetic materials in the development of new varieties, and farmers may have the right to save and re-use seeds from protected varieties for their own use (Helfer, 2002). The TRIPS agreement also allows members to exclude from patentability inventions whose use would seriously prejudice the environment. Implementation of this agreement is likely to increase the incentives for the developers of biotechnology innovations to expand into new markets, due to the increased protection it provides for their investment into the technology. Since agricultural biotechnology innovations are being produced mostly by the private sector, this protection is critically important for creating incentives among the suppliers of the technology for its dissemination.

The TRIPS agreement also has implications for the conservation and sustainable use of agricultural biodiversity. Agricultural biodiversity is maintained through systems of access and exchange from the farm to the international level, and property rights to plant genetic resources are likely to effect current patterns of exchange. There are several options for property rights over plant genetic resources, and their impacts on diversity are expected to be varied (Correa, 1999). Property rights and their degree of enforcement are also likely to impact the extent and nature of transgenic crop adoption, which will have implications for both spatial and temporal agricultural diversity (see Chapter 3; also Wright, 1998) The increased value of plant genetic resources as an input to breeding under private breeding programs may lead to increased demand for diversity (see Chapter 19). Concern that the establishment of property rights will lead to reduced levels of access and exchange of plant genetic resources and thus reduced levels of agricultural biodiversity have also been raised (FAO, 1998; Crucible Group, 1994). This includes concerns about the potentially negative impacts on access imposed by farmers' rights mechanisms (Gollin, 1998).

The agreements made under the WTO are not the only international agreements which drive the way the globalization of trade networks proceeds and impacts on biotechnology and biodiversity; there are several environmentally related conventions and agreements which are discussed in the following section and which may have an impact on the ways the WTO agreements are interpreted and implemented. However, the framework laid out under the WTO is the most important in determining what the potential impacts of trade liberalization on biodiversity and biotechnology will be, as this agreement has wide and expanding membership and its signatories include some of the key national players in this arena, which is not the case with many of the environmentally related agreements discussed below.

2. ENVIRONMENTALISM

Environmentalism has arisen from two main motivations: (1) the interest in preserving species, environmental quality, and ecosystems and (2) the concern about environmental and health side effects of agricultural practices. The 1957 publication of Rachel Carson's book, *Silent Spring,* was a major benchmark in the evolution of the environmental movement. It raised awareness about the negative side effects of pesticides and other agricultural practices. Over the last 30years, with a growing availability of information on the incidence and costs of environmental degradation, concerns over the necessity and means for controlling and reversing the process have become manifested in governmental policies from the international to the local level, as well as through activities in civil society. A key thrust of the environmental movement is the promotion of awareness of the nonmarket as well as market values of environmental goods and services and pressures to account for this value through government regulations as well as consumer behavior. Specific manifestations of the impacts of the environmental movement are considered in the next few paragraphs.

2.1 Establishment of environmental protection legislation and agencies

Since the late 1960s, most countries have established national agencies of environmental protection that are at the ministerial level and an increasing body of environmental regulations at all levels of government. However, in many cases the implementation of environmental regulation has been hampered because of political economic constraints of information about the processes that drive environmental degradation and the means to control them. There is a large body of evidence (Damania, Fredriksson, and List, 2003; Deacon 1999) showing that higher income countries attain higher standards of environmental quality and that corruption and flawed governance reduce the effectiveness of environmental policy.

The primary means of environmental regulation have been through the implementation of "command and control" measures, which are fairly blunt and achieve environmental objectives at excessive costs (Oates and Baumol, 1996). However, at present, there is gradual transition to financial incentives (payment for environmental services) and market-based mechanisms (trading in water rights or pollution permits). The regulation of chemical pesticides and drugs consists of strict preregistration testing and "learning by doing" once a product is released. The regulating authorities establish applications, standards, and tests for efficacy and side effects before registration. Products are recalled once a sever defect (carcinogenicity) is detected. The high cost of registration may be a barrier to entry, but it serves to address concerns about product safety and environmental impacts (National Research Council, 2000). Cropper et al. (1992), in an analysis of the regulations of pesticides in the United States, suggest that the Environmental Protection Agency is capable of weighing benefits and costs when regulating environmental hazards; however, the implicit value placed on health risks—$35 million per applicator cancer case avoided—may be considered high by some people. The same regulatory approach is used for genetically modified (GM) varieties. The effectiveness of this regulatory approach depends on quantitative understanding of the processes through which biotechnology affects the environment. For example, concerns about the buildup of pest resistance have led to the establishment of *refugia* requirements (demanding allocation of some land to nonmodified varieties) with *Bacillus thuringiensis* (Bt) cotton. The challenges of establishing and implementing these regulations are apparent from a growing body of literature on their evaluation (Laxaminarayan, 2002). Performance measures are also very difficult to establish for the conservation and sustainable use of agricultural biodiversity. There is uncertainty on the status, measurement, and value of biological diversity, both for wild and agricultural biodiversity.

Chapter 19 the irreversibility of the loss of genetic resources also creates difficulties in assigning performance measures.

Until recently, agricultural biodiversity conservation policies have focused primarily on the *ex situ* preservation of genetic resources associated with economically important crops. At present, the portfolio of policies includes *ex situ* gene banks, the establishment of botanical gardens and experiment stations, and various forms of incentive measures to promote *in situ* conservation. The former are mechanisms for preserving genetic resources, while the latter conserve evolutionary processes and human knowledge in addition to genetic resources.

2.2 International agreements on global environmental problems

Increasing concerns about global environmental problems and the need for international coordination in addressing them have given rise to a proliferation of international agreements. At the U. N. Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992, a basis was laid for several international agreements in the areas of biodiversity preservation, climate change, desertification control, and others. Of direct relevance to the management of biodiversity and biotechnology is the Convention on Biological Diversity (CBD). The CBD is an intergovernmental convention that entered into force in 1993, which has now been ratified by 180 parties with the aim to achieve three main goals: (1) the conservation of biodiversity; (2) sustainable use of the components of biodiversity, and (3) sharing the benefits arising from the commercial and other utilization of genetic resources in a fair and equitable way.

In January, 2000, a supplementary agreement to the CBD, known as the Cartagena Protocol on Biosafety, was adopted. This agreement seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern biotechnology. The two cornerstones of the Protocol are the concepts of Advance Informed Agreement (AIA) and the Precautionary Approach.[4] The AIA enables importing countries to subject all imports of Living Modified Organisms

[4] The CBD website on the Cartagena Protocol describes the Precautionary Approach: "One of the outcomes of the United Nations Conference on Environment and Development in 1992 . . . was the adoption of the Rio Declaration on Environment and Development, which contains 27 principles to underpin sustainable development. One of these principles is Principle 15 which states that 'In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.'"

(LMO's) to a risk assessment before allowing its entry, and such risk assessments may be made using a precautionary approach. This could have implications for the adoption of agricultural biotechnology, as this agreement could allow countries to block imports of seeds of GM plant varieties in the absence of sufficient scientific evidence about their safety. The agreement entered into force in September, 2003.

It is important to note that the members of the CBD and the Cartagena Protocol differ from the members of the WTO. Notably, the United States has not ratified the CBD (although it is a signatory) and is not a signatory to the CP and, as the primary developer and exporter of GM products, this is likely to have major implications for how these agreements are implemented. How these differences in legally binding commitments among countries will be resolved in international fora is still not clear, and there are attempts to try to harmonize any conflicting provisions (Josling, 1999). It is also not clear how varying standards for risk assessment allowed under the WTO and multilateral environmental agreements will be resolved. This will most likely emerge through dispute resolution and arbitration in international bodies (Anderson and Nielsen, 2001).

2.3 Proliferation of environmental groups in civil society

Public support for the environmental movement has been manifested by the establishment of nongovernmental organizations that emphasize various aspects of environmentalism. Some, like the Nature Conservancy, are engaged in the purchase of valuable environmental resources (mostly land and water), and others (e.g., Greenpeace) are engaged in political activism. Other key players include the World Conservation Union (IUCN) and the World Resources Institute (WRI), which play a role of information provision and policy support, and the World Wildlife Fund (WWF), which is engaged in the implementation of conservation-related projects. A key activity of many environmental groups is educating consumers on the environmental implications of various goods and services offered in the marketplace and the mobilization of pressure from consumers on producers through their purchasing decisions.

Several studies have found that the demand for environmental quality is related to income. The demand for environmental services and goods varies across income groups, with higher income categories being more likely to focus on conservation, while for lower income groups the sustainable utilization of natural resources is a more pressing concern. In developing countries major environmental concerns are related to problems of water quality, waste management, and sanitation, particularly in urban areas, as well as the sustainable use of natural resources in the process of economic development. Countries with higher income levels are more concerned with natural resource preservation, such as the preservation of open space, and the protection of endangered species. In general, concerns about global environmental goods and services, such as biodiversity and climate change, have been driven by developed countries, although there is increasing awareness and concern of the importance of these issues among developing countries.

3. CONSUMERISM

As income increases, consumer rights and preferences for improved quality have become the major determinant of economic activities. In most developed countries, the primary potential for revenue generation is through enhancing the value-added of food products. Indeed, in developed countries, sectors in the agricultural economy (e.g., poultry) that have been able to provide a wider variety of quality choices and extend their product mix have been very successful. Becker (1965) provided a conceptual framework to analyze consumer choices for improved product quality. They suggest that consumers derive enjoyment from the characteristics of market goods that they consume, and that consumption activities may entail some effort. For example, the value of a meal to a consumer may be comprised of the value of its nutritional content, its taste, its safety to consume, and the degree of effort that its preparation requires. Economic factors are a major determinant of food quality preferences. Some characteristics, such as convenience in preparation, exhibit higher elasticities of income. Cultural factors may also influence the values assigned to various food characteristics. Thus, one of the challenges of agricultural industries is to economically produce products that contain the food characteristics desirable in their target markets.

As income in developing countries rises, the demand for improved food quality is likely to increase significantly. In the next 50 years, we expect that vast populations in Asia and South America will reach income levels that will enable them to pursue improved food quality. Projections made by the FAO indicate that by 2015 rises in income will translate into consumption of an average level of over 3000 kcals/day/person by 54% of the world's population (Bruinsma, 2003). This increase in caloric intake will stimulate a transition in food consumption patterns as well, from starchy staples toward "luxury" goods such as dairy products, fish, and meat. The demand for food characteristics associated with a high elasticity of income, such as food safety, nutritional content, and convenience is thus also likely to increase.

According to Welch and Graham (2002), "Micronutrient malnutrition (e.g., Fe, Zn and vitamin A deficiencies) now afflicts over 40% of the world's population and is increasing especially in many developing nations. Green revolution cropping systems may have inadvertently contributed to the growth in micronutrient deficiencies in resource-poor populations. Current interventions to eliminate these deficiencies that rely on supplementation and food fortification programs do not reach all those affected and have not proven to be sustainable." They argue that one approach to the micronutrient deficiency problem is enhancing the nutritional content of staple food products.

One of the major promises of biotechnology is its potential to enhance food characteristics. Biotechnology may be used to extend shelf life, modify size and shape, and enhance flavors and nutritional content. Parker and Zilberman (1993) have shown that improved food quality may more than double the retail price of peaches, and quality-enhancing biotechnology may be a major source of income for agriculture in the long run. Environmental preferences are also manifested through consumer behavior. One dimension that may enhance the demand for biotechnology products is the desire to consume pesticide-free food.

At the same time, consumer concerns over the health and environmental impacts of biotechnology products is resulting in a slower rate of their adoption in agricultural production. On the health side, concerns over the potential for increased levels of allergic reactions from consuming foods generated through biotechnology have been raised. Environmental concerns have also been raised regarding the potential for genetically modified organisms (GMOs) to escape into the larger gene pool, resulting in an irreversible change in the composition of genetic resources and the potential for the spread of undesirable organisms such as "super weeds" (Rissler and Mellon, 1996).

A critical determinant of the future use of agricultural biotechnology products lies in the attributes consumers will demand of products and to what extent they will pay for these. At present this response is unclear and will be driven by conflicting concerns on environmental and food safety and the perception of biotechnology's impact on these, as opposed to the desire for quality characteristics biotechnology can deliver, such as improved taste and nutrition, enhanced shelf life, and also improved environmental performance associated with a reduction in pesticide use.

Considerable variations in consumer attitudes towards agricultural biotechnology products, particularly GMOs, are found in the potential markets for the products. Attitudes are often linked to income, with people from poorer countries having more positive attitudes than those from richer countries, although there are exceptions to the pattern (FAO, 2004). A survey conducted by Environics International in 34 countries revealed that, in general, people in developing countries are more likely to value the benefits of biotechnology over the potential risks, as compared with those in developed countries, particularly Europe. Consumer attitudes were also found to vary depending on the type of benefits biotechnology conveyed: Applications that address human health or environmental concerns were viewed more favorably than those that increase agricultural productivity.

Consumer rejection of GMOs has two major implications for the dissemination and adoption of agricultural biotechnology. Threat of loss of market share has caused exporting countries to ban the use of biotechnology in production, and this factor is now included in the risk-assessment procedures of some countries. For example, one of the largest soya-producing regions of Brazil banned the planting of GM soya and India stopped trials of BT cotton (FAO, 2004). Consumer demand for differentiated products has implications for the structure of the food processing industry as well. We have already seen the emergence of differentiated products in poultry and fresh fruits and vegetables in developed countries. Producers of these differentiated products are frequently either vertically integrated firms or a chain of firms that is linked through contracts. It is likely that some dominant firms in these industries (Proctor and Gamble, Gerber, etc.) will become actively involved in utilizing biotechnology to produce differentiated products. Both the marketing techniques and production structures that are associated with these industries are likely to transform the agricultural sectors that adopt biotechnology to meet differentiated consumer preferences. Increases in vertical integration and contracting in agriculture are likely to accompany the development of biotechnology to respond to these consumer demands.

4. DEMOGRAPHICS

Population growth and mortality rates will be key determinants of the composition and size of demand for agricultural production, and also the technology under which it is supplied. Increased populations generate increased demand for agricultural products, which must be supplied through an expansion or intensification of agricultural production. Demographic change is the key determinant of population pressures on the land, and thus important determinants of the rate and nature of agricultural intensification, with major implications for both biodiversity and biotechnology.

We are living in times of rapid and radical changes in population size and distributions. Global population growth rates are declining swiftly—from a peak of 2.04% per annum in the late 1960s to 1.35% per annum by the late 1990s (Bruinsma, 2003). It is projected to fall even further, to 1.1% per annum by 2015. Although rates are dropping, the absolute numbers of people added to the world's population each year are still quite large, particularly in developing countries. South Asia, East Asia, and Sub-Saharan Africa are the three areas where annual incremental population increases have been the highest over the past two decades and, thus, where a rapid growth in the working-age population is now occurring. Continuing large annual increases are projected to occur in South Asia and East Asia up to 2015. For Sub-Saharan Africa, however, the pandemic of HIV AIDS has resulted in a major shift in population projections and annual incremental increases, due to its impact on mortality rates among working age populations. In most of eastern and southern Africa the prevalence of HIV is over 10%. For some countries, negative population growth rates are projected by 2010 as the mortality from HIV outstrips new births (Jayne, Villareal, and, Pingali, 2004). Overall, the absolute numbers of adults projected to be alive in countries of Sub-Saharan Africa with HIV prevalence rates over 10% is roughly similar to what it is today. According to the projections, between 2000 and 2025 there will be a slight increase in the number of men between 20 and 59 years of age, but no change in the number of women (Jayne, Villareal, and, Pingali, 2004). However, HIV will also likely affect the productivity of the labor force, due to increased incidences of illness and lower capacity to perform work among afflicted laborers, as well as the need to divert labor to child care, funerals, and tending the sick among the population in general.

The impact of demographic change on agricultural technology choice and ultimately on biotechnology and agricultural biodiversity depends on the supply of factors of production aside from labor, such as land, capital, and technology. The distribution of these factors and policies that affect their relative prices will determine the degree to which an expansion in agricultural output will be met through increases in the extensive or intensive margin of agricultural production. FAO projects, which approximately 80% of the required growth in crop production will come from, increase in the intensive margin (i.e., increases in yields per hectare per year) (Bruinsma, 2003). Arable land expansion as a source of growth (the extensive margin) will be important in some Sub-Saharan and Latin American countries, although much less so than in the past.

In the past, and with the green revolution in particular, the intensification of agriculture and yield increases were accomplished partially through the adoption of improved varieties, which has also been associated with changes in crop genetic diversity, although there is some controversy over whether the direction has been negative or positive (see Chapter 3 for a detailed discussion; also Brush, 1999). The impacts of intensification on increasing crop genetic erosion and vulnerability are a serious concern (FAO, 1998; Matson et al., 1997). However, much of the areas where agricultural intensification through the adoption of monocultural systems has not yet taken place are characterized by a high degree of agroecological heterogeneity and poorly functioning markets, resulting in a higher value to maintaining diversity in the farming system (see Chapter 5). Intensification in these areas may require higher reliance on agricultural biodiversity due to the barriers to adoption of monocultural agricultural production systems (see Chapter 19; also Matson et al., 1997).

5. PRIVATIZATION AND DEVOLUTION

Many of the powers that governments wielded in the past have been transferred to the private sector or local governments in recent years. These processes of privatization and devolution are occurring parallel to the process of globalization; thus, we see a shift of power from national governments towards bigger international organizations as well as smaller, local governments and private firms. The logic of this devolution is an assignment of responsibilities that are scale appropriate and correspond to core competencies of organizations. There are several dimensions of privatization and devolution with implications for biotechnology and biodiversity, which will be discussed below.

5.1 The privatization of agricultural and life science research

One of the most striking areas where privatization has occurred is in the agricultural R&D industry, particularly those related to biotechnology. In the 1970s and 1980s developed countries experienced a major reduction in the amount of public funds devoted to agricultural research, accompanied by significant increases in private-sector spending (Pray and Umali-Deininger, 1998; Alston, Pardey, and Smith, 2000). In developing countries private sector-funded research is still a much smaller share of total research, but increases are occurring there as well. Declining public budgets, poor performance record of publicly funded research, increased appropriability of the returns to privately funded research due to IPRs, and the increased use of purchased inputs in agriculture as a result of increasing competition all contribute towards an increased role of private-sector funding in agricultural research.

Private firms in developed countries largely dominate the R&D of agricultural biotechnology with an estimated $2.6 billion invested in 1998 (Byerlee and Echeverria, 2000). Only a small share of this investment is directed towards developing countries. There are significant market failures in harnessing the benefits of biotechnology for the benefits of poor producers and consumers in developing countries, which are discussed in detail in Chapter 3. Several chapters (3, 4, 13, 14, 17, and 18) note that a key determinant of the degree to which biotechnology R&D can be harnessed for addressing the needs of developing countries is the capacity of the public sector research institutions to access the technologies generated in the private sector of developed countries. There is tremendous variation in this capacity among developing countries, both in terms of handling the science and the institutional issues involved (Byerlee and Echeverria, 2000). Forging innovative links between private and public R&D systems is an important way to create better access to biotechnology in developing countries and one which is taken up in other chapters of this book.

5.2 Privatization of natural resource property rights and expansion of trading schemes

Land reform and the decollectivization of commonly held properties have been major trends in transition economies and developing countries in recent years. Lands that previously belonged to the state or other forms of communal ownership have been allocated to individual owners who obtain property rights for utilization of the land and its resources. These measures are intended to eliminate inefficiencies that existed under centrally planned economies and inequities in distribution in others. At the same time a move to privatize natural resources and environmental services together with the introduction of market trading to improve environmental management has arisen—although on a much smaller scale. For example, individual rights to water and water trading are being introduced in countries such as Chile and the United States and are being considered in several countries in South America and South Asia. Carbon emission reduction credits is another area where trading regimes have been established and which have the potential for considerable expansion depending on the nature of future international agreements to control climate change. In the area of agricultural biodiversity, international agreements on the potential for establishing transfer mechanisms to pay for the conservation of resources, such as the International Treaty on the Conservation and Utilization of Plant Genetic Resources and the CBD have been established, although considerable work still needs to be done on the design and implementation (see Chapters 8 and 9).

The privatization of land and land reform could provide producer incentives for the adoption of biotechnology—to the extent that it contributes towards productivity gains, but impacts on biodiversity are less clear. Where land reform programs involve use of forested lands or previously uncultivated lands for agriculture, then impacts on wild biodiversity are likely to be negative.

The privatization and commoditization of other natural resources and environmental services provide farmers and natural resource owners with more flexibility and may provide them with incentives to provide environmental goods and services, such as biodiversity.

5.3 Privatization of extension and emergence of private agricultural consultants

Many countries are experimenting in privatizing some of the services that public sector agricultural extension has provided.[5] These reforms reflect both increased scarcity in public funds and the new reality where agriculture becomes more knowledge intensive, and farmers operating in the commercial sector are looking for more detailed and specialized knowledge and are ready to pay for it. In the United States and other industrialized countries (Wolf, 1998), dealers of input manufacturers (irrigation equipment and seed and chemical companies) have increased the amount of management information that they provide to farmers. The complexity of pest control decisions and the need to comply with environmental regulations have led to the emergence of independent pest control consultants. In specialty crops where contracting is prevalent, the buyers may dictate some production practices and provide technical assistance to the contractors. As farms grow in size, they may hire their own specialists in pest control and other aspects of production and design their own production systems.

In many regions, state extension specialists now provide advice and training to independent consultants, provide general retraining to farmers and farm workers, address some of the needs of smaller farms, specialize in treating regional problems (conflict resolution among farmers, environmentalists, and the urban sector), and provide information on the requirements and means to meet environmental regulations. Extension centers are also used to adapt and test new technologies under local conditions. With a decrease in the role of the public sector in providing information to farmers, a need for an overall increase in the resources allocated to education and the transfer of information has arisen. In developed countries there has been some response to this need, but in many developing countries there is still a considerable lack of resources devoted to education and information transfer with a consequent negative impact on the ability of farmers to assess and adopt new technologies.

5.4 Reduction in size and increased specialization of central governments

The reduction in the responsibilities of state governments is also associated with a reduction in taxation to support state governments (or at least a reduction in the rate of growth of taxation). Moreover, a larger share of the tax revenues of the central governments is returned to local governments that actually provide services. There are several

[5] See Wolf (1998) for evidence for England, Australia, and New Zealand. Some countries in Latin American, notably Nicaragua, are going through similar transformations.

government agencies now attempting to subcontract provision of key services (waste management and education) to private companies, thus significantly reducing the size of the public sector. Governments are attempting to concentrate on the areas that they do best, such as provision of public goods such as national defense, support for basic research, and monitoring and enforcement of environmental protection and economic competitiveness.

The declining role of central governments and the transfer of responsibilities to the private and nongovernmental sectors may lead to increased efficiency but may also lead to gaps in unsatisfied needs, and new arrangements need to be established to fill these gaps. In some cases, the reduced role of the central governments may negatively affect the poor, at least in the short run. On the other hand, the realignment of responsibilities will provide more resource mobility and flexible institutional infrastructure that will enable faster adoption of biotechnology innovations and better conservation of biodiversity.

Devolution changes the scale at which transfers are made and may create conflicts between local needs and the provision of goods and services that are national or global in scope. Biodiversity conservation clearly benefits a wide group but requires cost bearing at a local level, so there is a need for some sort of mechanism to address this. In terms of agricultural biodiversity, the relevant scale for management is often broader than the local level, which also creates some coordination problems. Thus, devolution may have opposing effects on the management of biodiversity, and increasing flexibility in management at the local level may be positive but can be offset by a decrease in the potential for coordination at higher levels.

6. THE EMERGENCE OF INFORMATION AND KNOWLEDGE ECONOMICS

Arguably, the dominant form of technological change in the last 25 years has been in the area of information, communications, and data processing. Over the last 25 years, we have witnessed drastic reductions in the cost of data processing and the proliferation of computer use among families and small firms, emergence of global communications networks that enable instantaneous financial transactions and fast, massive transfer of data across locations, and establishment of a network of satellites that facilitate monitoring of resource management with a high degree of accuracy. The emergence of the information economy has important implications for both biotechnology and biodiversity in terms of its impact on the capacity to develop new technologies and the institutions that are needed to promote such development, the introduction of modern production methods which are responsive to environmental heterogeneity, the analysis and monitoring of agricultural production impacts on environmental conditions, and the ability to inform and mobilize large groups of people over large geographic distributions.

The development of biotechnology has benefited largely from the increase in computational abilities. Biotechnology is data intensive, and mapping of genes would not have been feasible without advanced computer technologies. With information-intensive technologies such as biotechnology, most of the economic value is not attributed to equipment (hardware) but, rather, to management knowledge and information (which are in many cases embodied in software). Thus, with the evolution of information technologies, we have seen much more emphasis on establishing definitions and enforcement criteria for IPRs. Without the ability to capture accrued rents using software or new knowledge of information, private parties would not have the incentive to develop these items. Therefore, both patent and copyright laws have been modified to protect IPRs, and the extent of their coverage is being expanded through international trade agreements such as the TRIPS agreement under the WTO.

Establishing and protecting international IPRs for biotechnology innovations is a major challenge. A narrow definition of IPRs for biotechnology innovations may not provide sufficient incentives to cover R&D costs. On the other hand, a definition that is too broad may give owners of these rights excessive monopolistic power and deter access and further innovations by others. IPRs for the knowledge embodied in biotechnology need to take into account the contribution that indigenous knowledge has played in the development of an innovation and assign value to these rights accordingly. However, assigning property rights to goods that were previously freely available and exchanged among farmers could also reduce the accessibility to those resources and actually reduce diversity (see Chapter 9).

6.1 Adoption of precision agriculture

Precision agriculture can be defined generically as a bundle of technologies that adjusts input use to variations in environmental and climatic situations over space and time and reduces residues associated with input use. Many of these technologies rely on space age communication technologies and incorporate the use of geographic positioning systems (GPS). Modern irrigation technologies that adjust input use according to variability in soil and weather conditions relying on weather stations and moisture-monitoring equipment are also examples of precision technologies. Precision technologies have the potential to increase input-use efficiency, increase yields, and reduce residues of chemicals that may contaminate the environment. In many cases it may lead to input saving, but in others the yield effect may also entail increased input use (National Research Council, 1997).

Thus far, there have been significant variations in adoption rates of technology that can be generically defined as precision technologies. Some modern irrigation technologies have high rates of adoption in high value crops. Some components of what is promoted as "precision agriculture" such as yield monitors are gaining significant acceptance. But, overall, adoption rates of many components of precision agriculture have not been very high even in developed countries (National Research Council, 1997). Adoption of precision farming technologies may be hampered by the cost of investment. Furthermore, the management software needed to take advantage of the information has not been fully developed. Adoption of precision farming technologies will likely increase in the future as their cost declines, as productivity increases, and as new management software becomes available.

Precision technologies may both complement and substitute for biotechnologies. Precision technologies that enable the planting of a field with several varieties of seeds will increase the demand for diversified genetic stock that can be adjusted to slight variations in soil conditions. Precision agriculture may also improve sorting and harvesting methods, making the production of high-quality produce more economical and improve incentives to develop higher quality varieties. On the other hand, precision farming may reduce significantly the environmental side effects of pesticides and provide more refined mechanical ways to address weed problems, thus, reducing the demand for some of the pest control applications of biotechnologies and reducing the loss of biodiversity stemming from inadvertent contamination.

6.2 Introduction of precision and information technologies for the management of biodiversity

Some of the major problems with biodiversity conservation and management may be better addressed with applications of precision technologies. By-catch, the destruction of nontarget species by fishermen, is a major environmental side effect in fisheries. Similarly, forest clearcutting is a major cause of biodiversity loss. Adoption of more refined harvesting technologies may reduce these side effects and, thus, result in higher levels of biodiversity preservation. However, both the development and adoption of such technologies may not occur, at least in a socially optimal manner, unless financial incentives are introduced. These may include subsidization of research and technology adoption as well as penalties and regulations on harvesting technologies that damage the environment. Monitoring and enforcement of such incentives provide a significant challenge, but taking advantage of emerging technologies in remote sensing can solve some of the technological aspects.

6.3 Improved marketing and product flows

Computer technologies enable the documentation and monitoring of sales in real time and instantly provide useful information on inventory conditions and producers' preferences. Thus, marketers and distributors can obtain a faster response and reduce inventory costs. Also, marketers may be able to better identify quality preferences at specific locations and respond to them more promptly. Indeed, some of the recent product diversification in agriculture, especially in the poultry and produce sectors, took advantage of new information technologies, resulting in a higher quality and more diversified product. The efficiency gains that modern information technologies provide in marketing quality-differentiated products is likely to enhance the introduction and adoption of biotechnology.

Information technologies reduce the cost of product differentiation in agriculture, but also increase the relative advantage of contracting and vertical integration. The introduction of a new brand of differentiated products requires precise coordination among retailers (who provide the shelf space), distributors, and producers. It is subject to a strict timetable. The organization responsible for providing a new differentiated product to a retail chain will prefer to contract with farmers to produce a new product or control the production itself. Thus, the introduction of differentiated biotechnology products will be associated with "industrialization" of agriculture, including increased contracting and vertical integration.

7. CONCLUSIONS

There are several forceful and rapidly moving processes occurring globally that will affect the management, and ultimately the status, of biotechnology and biodiversity. In this chapter we have given an overview of some of the major social, political, and economic forces that we believe will shape the way in with the two "bios" will co-evolve with humankind. Of course, the processes we have focused upon here are not the only ones which will affect how biotechnology and biodiversity issues are resolved, and their relative importance will vary among countries. Climate change could have a major impact on the demand for agricultural technology, as well as international agricultural supply and production, and thus affect both biodiversity and biotechnology.

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